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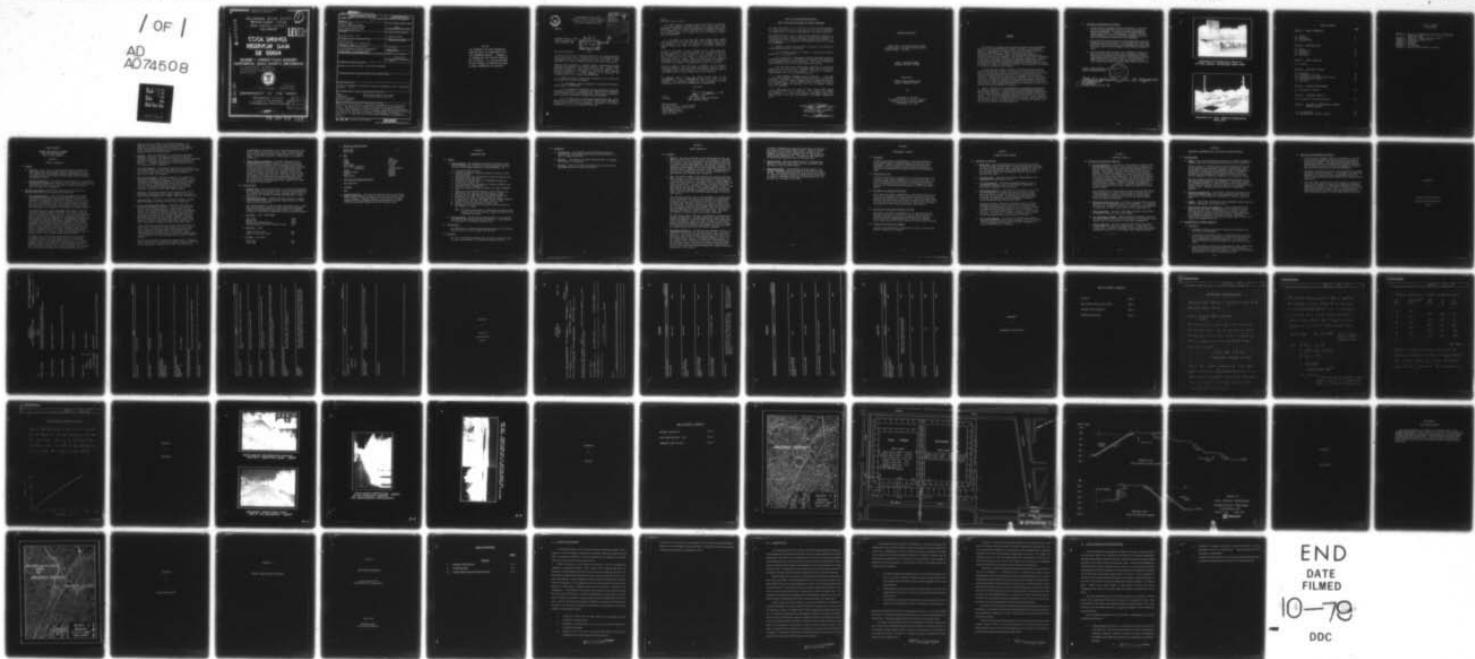
NEW JERSEY DEPT OF ENVIRONMENTAL PROTECTION TRENTON
NATIONAL DAM SAFETY PROGRAM. COOL SPRINGS RESERVOIR DAM (DE-000--ETC(U))
JUL 79 J J WILLIAMS

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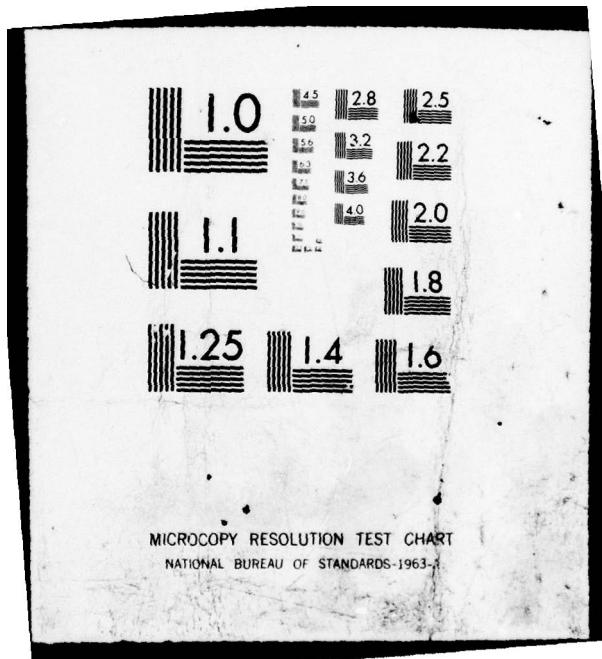
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BRANDYWINE CREEK,
NEW CASTLE COUNTY
DELAWARE

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COOL SPRINGS
RESERVOIR DAM
DE 00014

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM.

Cool Springs Reservoir Dam (DE-00014),
Delaware River Basin, Brandywine Creek,
New Castle County, Delaware. Phase 1
Inspection Report.



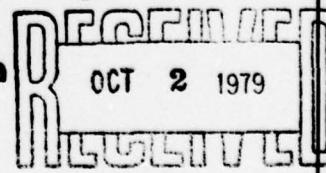
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DEPARTMENT OF THE ARMY

Philadelphia District
Corps of Engineers
Philadelphia, Pennsylvania

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NE00014	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Phase I Inspection Report National Dam Safety Program Cool Springs Reservoir Dam New Castle County, Del.	5. TYPE OF REPORT & PERIOD COVERED FINAL	
7. AUTHOR(s) Williams, John J. PE	6. PERFORMING ORG. REPORT NUMBER DACW61-79-C-0011	
9. PERFORMING ORGANIZATION NAME AND ADDRESS O'Brien & Gere Suite 1760, 1617 J.F. Kennedy Blvd. Philad. Pa 19103	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, Philadelphia Custom House, 2d & Chestnut Streets Philadelphia, Pennsylvania 19106	12. REPORT DATE July, 1979	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	13. NUMBER OF PAGES 50	
	15. SECURITY CLASS. (of this report) Unclassified	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Copies are obtainable from National Technical Information Service, Springfield, Virginia, 22151.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
Dams Eembankments Structural Analysis Visual Inspection	National Dam Inspection Act Report Cool Springs Reservoir Dam, Del.	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report.		

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Honorable Pierre S. DuPont
Governor of Delaware
Dover, Delaware 19901

20 SEP 1979

Dear Governor DuPont:

Inclosed is the Phase I Inspection Report for Cool Spring Reservoir Dam in New Castle County, Delaware which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given in the front of the report.

Based on visual inspection, available records, calculations and past operational performance, Cool Spring Reservoir Dam, a high hazard potential structure, is judged to be in fair overall condition. The dam has no spillway but is capable of storing the entire Probable Maximum Precipitation. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. Within six months from the date of approval of this report the following actions should be initiated:

(1) Piezometers should be installed to determine the phreatic surface within the embankment.

(2) A subsurface investigation should be performed during the piezometer installations to determine the composition and properties of the embankment and foundation materials. Soils tests and stability analyses should be performed to assess existing conditions.

(3) The stone masonry retaining wall supporting the 10th street slope should be repointed and the missing stone blocks replaced to maintain the wall's structural integrity. According to the Owner's representative, this work is presently under way.

NAPEN-D

Honorable Pierre S. DuPont

b. Future reservoir drawdowns should be performed at a slow rate to allow safe dissipation of possible excess pore pressures within the embankment. Procedures should be established for reading water levels in the piezometers at regular intervals during drawdown to insure a safe balance between the reservoir pool and the phreatic surface within the embankment.

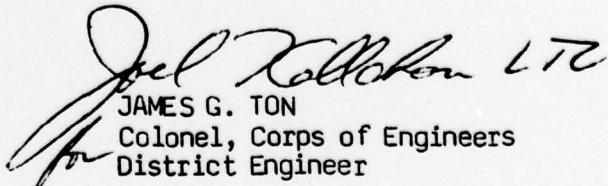
c. The period of time that the basins remain empty during cleaning operations should be minimized. This procedure will reduce the possibility of excess pore pressure development within the Franklin Street slopes which are exposed to the regional groundwater table.

A copy of the report is being furnished to Mr. John Wilson III, Delaware Department of Natural Resources and Environmental Control, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congressman Thomas B. Evans. Under the provision of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, five days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely,



JAMES G. TON
Colonel, Corps of Engineers
District Engineer

1 Incl
As stated

Copies Furnished:

Mr. John Wilson III, Acting Secretary
Department of Natural Resources and
Environmental Control
Edward Tatnall Building
Dover, DE 19901

COOL SPRING RESERVOIR DAM (DE00014)

CORPS OF ENGINEERS ASSESSMENT OF GENERAL CONDITIONS

This dam was inspected on 24 May 1979 by O'Brien & Gere Engineers, Inc. under contract to the U.S. Army Engineer District, Philadelphia, in accordance with the National Dam Inspection Act, Public Law 92-367.

Cool Spring Reservoir Dam, a high hazard potential structure, is judged to be in fair overall condition. The dam has no spillway but is capable of storing the entire Probable Maximum Precipitation. To insure adequacy of the structure, the following actions as a minimum are recommended:

a. Within six months from the date of approval of this report the following actions should be initiated:

(1) Piezometers should be installed to determine the phreatic surface within the embankment.

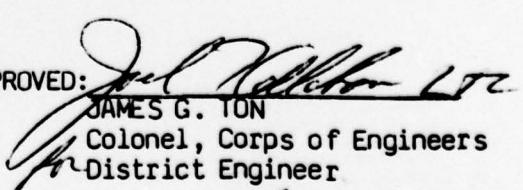
(2) A subsurface investigation should be performed during the piezometer installations to determine the composition and properties of the embankment and foundation materials. Soils tests and stability analyses should be performed to assess existing conditions.

(3) The stone masonry retaining wall supporting the 10th street slope should be repointed and the missing stone blocks replaced to maintain the wall's structural integrity. According to the Owner's representative, this work is presently under way.

b. Future reservoir drawdowns should be performed at a slow rate to allow safe dissipation of possible excess pore pressures within the embankment. Procedures should be established for reading water levels in the piezometers at regular intervals during drawdown to insure a safe balance between the reservoir pool and the phreatic surface within the embankment.

c. The period of time that the basins remain empty during cleaning operations should be minimized. This procedure will reduce the possibility of excess pore pressure development within the Franklin Street slopes which are exposed to the regional groundwater table.

APPROVED:


JAMES G. TON
Colonel, Corps of Engineers
District Engineer

DATE: 19 September 1979

DELAWARE RIVER BASIN

Name of Dam: Cool Spring Reservoir Dam
County & State: New Castle County, Delaware
Inventory Number: DE 00014

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Prepared by:

O'BRIEN & GERE ENGINEERS, INC.
JUSTIN & COURTNEY DIVISION

For

DEPARTMENT OF THE ARMY
Philadelphia District, Corps of Engineers
Custom House-2nd & Chestnut Streets
Philadelphia, PA 19106

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

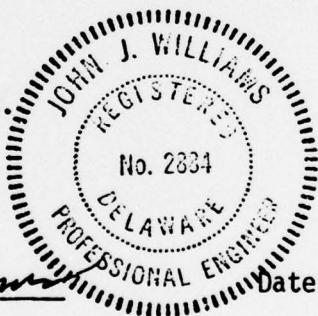
In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

b. Operation and Maintenance Procedures

1. Future reservoir drawdowns should be performed at a slow rate to allow safe dissipation of possible excess pore pressures within the embankment. Procedures should be established for reading water levels in the piezometers at regular intervals during drawdown to insure a safe balance between the reservoir pool and the phreatic surface within the embankment.
2. The period of time that the basins remain empty during cleaning operations should be minimized. This procedure will reduce the possibility of excess pore pressure development within the Franklin Street slopes which are exposed to the regional groundwater table.
3. Since the normal operating pool level fluctuates to within 1.5 feet of the dam crest, the Owner should develop and implement procedures for frequent or continuous measurements of reservoir stage during periods of heavy rainfall. As an alternative, the Owner could install an audible high stage warning device to alert operating personnel of extreme high reservoir elevations.

O'BRIEN & GERE ENGINEERS, INC.
JUSTIN & COURTNEY DIVISION



John J. Williams
John J. Williams, P.E.
Vice President
Delaware Registration No. 2884

Date: 24 August 1979



OVERVIEW OF COMPLETED REPAIRS
ON COOL SPRING RESERVOIR APRIL 1978



OVERVIEW OF COOL SPRING RESERVOIR
MAY 1979

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PHASE I REPORT

NATIONAL DAM INSPECTION PROGRAM
COOL SPRING RESERVOIR DAM
NDI I.D. NO. DE 00014

SECTION 1

PROJECT INFORMATION

1.1 General

- a. Authority. This report is authorized by the Dam Inspection Act, Public Law 92-367, and has been prepared in accordance with contract #DACW 61-78-C-0052 between O'Brien & Gere Engineers, Justin & Courtney Division and the United States Army Corps of Engineers, Philadelphia District.
- b. Purpose of Inspection. The purpose of this inspection is to evaluate the structural and hydraulic condition of the Cool Spring Reservoir and appurtenant structures and to determine if the dam constitutes a hazard to human life or property.

1.2 Description of Project (Information obtained from the City of Wilmington, Department of Public Works, Water Division).

- a. Dam and Appurtenances. The Cool Spring impoundment was created by excavation into a hillside slope and the construction of an enclosing earth embankment around the periphery. The brick lined reservoir is rectangular in shape and is divided into two basins by a 16.5 foot high earth dike. The interior slopes are covered with two courses of brick masonry and the basin floors are lined with unmortared brick placed on a clay blanket of unknown thickness.

The dam consists of an earth embankment approximately 1,468 feet long with a maximum height of 23.5 feet. The interior slope is 1.5H:1V and the crest width is 17 feet. The 10th Street embankment slope is 1.5H:1V and is supported by a stone masonry retaining wall as shown on Plate 3, Appendix E. The embankment length along 10th Street is about 288 feet and has a maximum height of about 14 feet at the southeast corner of the reservoir. The exterior embankment slope parallel to Van Buren Street varies from 1.5H:1V to 2.H:1V and is provided with two 12 foot wide berms as shown on Plate 3. This portion of the dam has a length of about 690 feet and has a maximum height of 23.5 feet. The northern exterior slope is 1.5H:1V, has a length of 490 feet and a maximum height of about 18 feet at the northeast corner of the reservoir.

Discharges into or out of Cool Spring Reservoir are controlled by combined shut-off and check valves located in a gatehouse situated at the toe of the Van Buren Street slope. Two 30-inch diameter conduits (one connected to each basin) can be used for supplying water to the reservoir or for discharge to the city water distribution system. Two 12-inch drain pipes, one connected to each of the 30-inch conduits and discharging into the city

sewer system, are available for reservoir drawdown. In addition, a 16-inch intake conduit connected to the high service water system is buried in the crest of the Van Buren Street slope and discharges into the reservoir near the southeast corner of the south basin.

- b. Location. Cool Spring Reservoir is an offstream impoundment located 0.5 miles west of Brandywine Creek in the City of Wilmington, Delaware. The reservoir is shown on the USGS Quadrangle entitled, "Wilmington North, Del." at coordinates N39° 45.1', W75° 33.6'. A regional location plan of Cool Spring Reservoir is enclosed as Plate 1, Appendix E.
- c. Size Classification. The maximum height of 23.5 feet which is less than 40 feet, and the storage capacity of 123 acre-feet, which is less than 1,000 acre-feet, place Cool Spring Reservoir Dam in the "Small" size category.
- d. Hazard Classification Cool Spring Reservoir is situated in a residential neighborhood within the City of Wilmington. The topography surrounding the embankment is such that overtopping or failure of the embankment would cause flood waters to be directed towards adjacent dwellings, schools and churches, resulting in excessive damage to property and loss of life. Therefore, the dam is in the "High" hazard category.
- e. Ownership. Cool Spring Reservoir Dam is owned by the City of Wilmington, Department of Public Works, Water Division, 800 French Street, Wilmington, DE. 19801. Telephone: 1-302-571-4171.
- f. Purpose of Dam. The dam was constructed to impound a treated water distribution reservoir for the City of Wilmington.
- g. Design and Construction History. Cool Spring Reservoir was constructed between 1873 and 1877. There are no records pertaining to the original design or construction of the dam. However, O'Brien and Gere Engineers, Inc., Justin and Courtney Division was retained in 1976 to investigate the feasibility of covering the reservoir and evaluate the condition of the embankment and brick lining. A visual inspection performed, while the south basin was drained for cleaning, revealed the presence of bulges in the center dike slope, cracking of the brick lining and an adjacent sand boil on the basin floor.

Similar conditions were observed at other locations within the south basin. In addition, it was noted that a 3 inch thick layer of shotcrete had been placed on the northeast corner slope adjacent to the basin drain. The shotcrete slope extended beyond the prevailing grade line of the interior basin slopes suggesting that there had been previous slope instability problems.

During the performance of temporary remedial repairs in January, 1978, a slope failure occurred on the Franklin Street (uphill) end of the south basin. Stabilization of the slope failure was

accomplished by construction of a 10 feet high berm across the entire length of the Franklin Street slope. The berm was provided with an impervious liner to prevent the loss of stored water. A detailed discussion of these repairs is included in Appendix G.

- h. Normal Operating Procedures. The normal operating pool is maintained by discharging treated water into the north basin through the 30-inch pressure conduit connected to a pumping station on the Brandywine Creek. The 30-inch conduit connected to the south basin is normally used for distribution to the city water system since normal pool elevation is above the crest of the center dividing dike. Reservoir levels are monitored on a regular basis (at least three times a day) so that lost storage is recovered during each 24 hour period. Reservoir fluctuations, according to the Owner's representative, Mr. Hanley, vary from approximately Elev. 142.0 to Elev. 145.0 during each 24 hour period.

1.3 Pertinent Data

- a. Drainage Area. Cool Spring Reservoir is an offstream impoundment which is isolated from surface runoff by the local topography and by catchment basins connected to the City sewer system. The surface area of the reservoir at maximum operating pool is about seven acres.
- b. Discharge at Dam Site. Discharge from the reservoir is accomplished through manually operated gate valves located in a gatehouse east of the reservoir.

Cool Spring Reservoir is used for water distribution and is dependent upon discharge through a pressure conduit from a pumping station on the Brandywine Creek; construction of an emergency spillway for flood control apparently was not considered necessary.

c. Elevation. (Feet - USGS DATUM)

Top of Dam	146.5
Normal Pool	142.0
Maximum non-overtopping pool	146.5
Minimum groundline at toe of exterior slope	123.0

d. Reservoir. (feet)

Length of Normal Pool	650
Length of Pool (top of dam)	660

e. Storage. (acre-feet)

Normal Pool	98
Top of Dam	123

f. Reservoir Surface (acres).

Normal Pool
Top of Dam

7
7

g. Dam.

Type	Earth
Length	1,468 feet
Height	23.5 feet
Crest width	17 feet
Side Slopes (interior)	1.5H:1V
(exterior)	1.5H:1V-2.0H:1V
Zoning	Unknown
Impervious Core	Unknown
Cutoff	Unknown
Cout Curtain	Unknown

h. Diversion and Regulating Tunnel.

Not applicable.

i. Spillway.

None

j. Regulating Outlets. The reservoir outlet consists of two 30-inch conduits (one draining each basin) which are controlled by valves in the gatehouse. Complete drawdown of the reservoir is accomplished by allowing discharge from the 30-inch outlets to drain into the sewer system through two 12-inch diameter pipes.

SECTION 2
ENGINEERING DATA

2.1 Design

- a. Data Available. The information available for review of Cool Spring Reservoir Dam includes the following obtained from both the City of Wilmington and O'Brien & Gere Engineers, Inc.
1. Cool Spring Reservoir Plan.
 2. Schematic drawing of City Water System in vicinity of Cool Spring Reservoir.
 3. Cool Spring Reservoir, Evaluation of Present Conditions and Alternate Covers, May 1977.
 4. Report on Cool Spring Reservoir, Embankment Leakage and Instability, October 1977.
 5. Cool Spring Reservoir, Evaluation of Present Conditions and Reservoir Covers, December 1977.
 6. Cool Spring Reservoir Repairs, Contract No. 78017, November 1977.
 7. Survey Grid for Monitoring Northwest face of Reservoir by MANN-TALLEY, INC. Dwg. No. 5521-L, February 3, 1978.
 8. As Built Survey, SOUTH BASIN OF COOL SPRING RESERVOIR by MANN-TALLEY, INC. Dwg. No. 5563-L, March 31, 1978
 9. As Built Cross Sections, SOUTH BASIN OF COOL SPRING RESERVOIR by MANN-TALLEY, INC. Dwg. No. 5565-L, April 6, 1978.
 10. Repairs to Cool Spring Reservoir, August 1978.
 11. Photographs taken after slope failure and during repairs to the reservoir in 1978.

NOTE: No design calculations or construction drawings for the original work on the reservoir between 1873 and 1877 are available for review.

- b. Design Features. The principal design features for the structure are shown on the drawings enclosed in Appendix E. A description of the features is discussed in Section 1.2.a.

2.2 Construction

No information is available concerning construction of Cool Spring Reservoir which was built between 1873 and 1877.

2.3 Operation

The City of Wilmington maintains daily records of reservoir depth and water system demand at the Brandywine pumping station.

2.4 Evaluation

- a. Availability. All information made available was obtained from the City of Wilmington and O'Brien & Gere Engineers, Inc., Justin & Courtney Division.
- b. Adequacy. The drawings and reports made available are adequate for a Phase 1 investigation.
- c. Validity. There is no reason to question the validity of the data obtained from the City of Wilmington.

SECTION 3
VISUAL INSPECTION

3.1 Findings

- a. General. The field inspection of Cool Spring Reservoir Dam took place on May 24, 1979. At the time of the inspection, the reservoir water surface was approximately 3.5 feet below the dam crest. No underwater areas were inspected. The dam was found to be constructed in general conformance with the available drawings. The observations and comments of the field inspection team are in the checklist which is Appendix B of this report. The appearance of the facility indicated that the dam is in fair condition and its appurtenances are reasonably well maintained.
- b. Dam. The interior slopes of the reservoir are covered with brick masonry which is in turn coated with shotcrete from the dam crest to 5 feet below the crest. The cement mortar is severely deteriorated such that samples of the material can be crushed between the thumb and forefinger. In many instances, the mortar has eroded away from the face of the brick to a depth of about 3 inches. Some small bushes were observed to be growing between the top of the shotcrete and the capstones located at the crest of the interior slope. The shotcrete lining exhibited some evidence of spalling and cracking.

The crest and exterior slopes of the embankment are predominantly grass covered while some small bushes and vines are also growing on the north slope. No evidence of vertical or horizontal misalignments were observed in the crest or exterior slopes during the inspection. An 8-inch diameter pipe outlet was noted at the toe of the north slope near the northeast corner of the reservoir. The pipe appeared to be aligned parallel to the toe and was discharging clear water at a rate of less than 1 gpm. The origin and purpose of the pipe could not be readily determined.

The 10th Street slope of the dam is supported by a vertical stone masonry retaining wall. In some locations the cement mortar has eroded to a depth of 4 inches from the surface of the stone blocks. A few of the smaller stones (less than 15 inches in the longest dimension) have been removed or have fallen from the wall. There was no indication of horizontal misalignment, vertical settlement or seepage through the wall at the time of inspection.

- c. Appurtenant Structures. The gatehouse has undergone extensive reconstruction within the last year and appears to be in excellent condition. The structure above grade has been demolished and replaced by a small brick building allowing access to a vault containing the control valves. The manually operated valves are in fair condition and, according to the Owner's representative, are all operable except for the two valves used to control drainage into the sewer system. (According to the Owner's representative, the 12" drain valves were repaired between the inspection date and preparation of this report)

A recently renovated four story brick pump house is located at the corner of 10th and Van Buren Streets. Inspection of the basement of this structure indicated the presence of clear seepage discharging at an estimated rate of 1 gpm through the stone masonry foundation wall. The depth of these seeps was at least 10 feet below the floor of the south basin.

- d. Reservoir Area. Cool Spring Reservoir has no drainage area since it is isolated from surface runoff by catchment basins connected to the City sewer system.
- e. Downstream Channel. All discharges from the reservoir are through underground conduits connected to the water or sewer systems. The potential hazard area to the east of Cool Spring is a park and playground used by an adjacent Elementary School. In addition, Interstate 95 has been constructed just east of the park in a cut about 30 feet deep.

SECTION 4

OPERATIONAL FEATURES

4.1 Procedures

According to the Owner's representative, Cool Spring Reservoir is an integral part of the water supply system for the City of Wilmington. Reservoir levels are checked at least once each eight-hour shift by personnel on-site 24 hours a day and are controlled by discharge from a pumping station on the Brandywine Creek.

4.2 Maintenance of Dam

According to the Owner's representative, the grass growing on the crest and slopes of the embankment is cut on a regular basis. Inspection and maintenance of the interior slopes of the reservoir are performed during regular periods of full drawdown which are necessary for removing accumulated deposits of debris and organic matter.

4.3 Maintenance of Operating Facilities

According to the Owner's representative, the combined shut-off and check valves associated with daily operation of the reservoir are inspected and repaired on a regular basis. The valves controlling discharge into the 12-inch drain pipes connected to the sewer system were not exercised during the inspection. According to the Owner's representative, these valves have recently been repaired.

4.4 Description of any Warning Systems in Effect

According to the Owner's representative, city personnel on-site have been directed to inform Mr. Paul Henry, General Manager of the Water Division, of any unusual conditions at the dam site. In the event of an impending failure, Mr. Henry will contact local authorities who will alert residents of the critical situation.

4.5 Evaluation of Operational Adequacy

Inspection and maintenance of operating facilities at Cool Spring Reservoir appears to be adequate.

SECTION 5

HYDRAULICS AND HYDROLOGY

5.1 Evaluation of Features

- a. Design Data. Cool Spring Reservoir has a surface area of about 7 acres, a maximum storage capacity of 123 acre-feet and a drainage area equal to the reservoir area. Emergency drawdown of the reservoir can be accomplished by discharging from both basins into the City water system and simultaneously into the two 12-inch diameter drain pipes.
- b. Experience Data. According to the Owner's representative, the maximum pool of record was E1.146.0.
- c. Visual Observations. The entire embankment appears to be in satisfactory condition with no indications of embankment instability at the time of the inspection.
- d. Overtopping Potential. Since there is no spillway at this site and the reservoir is isolated from surface runoff, a design storm was used to evaluate the adequacy of the drain system. Based upon the dam height, storage capacity and hazard classification, the design storm was selected to be 50 percent of the Probable Maximum Precipitation (PMP).

Hydrologic analyses indicate that the PMP is about 21 inches. Drawdown calculations indicate that the 12 inch drains alone are capable of discharging 70 percent of the additional storage resulting from the PMP (See Appendix C for calculations). In addition, the normal operating pool is about 4.5 feet below the dam crest. The reservoir is capable of storing the entire PMP without overtopping under normal operating conditions.

- e. Drain System Adequacy. In the event of insufficient reservoir capacity to store the design storm, operation of the drain system will discharge more than one-half of the PMP, therefore, the system is considered to be adequate.

SECTION 6

STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations. The interior slope failure of February 1978 and the appearance of bulges in the slopes at other locations in the south basin leads to the conclusion that the stability of the slopes is questionable, especially during periods of reservoir drawdown. In addition, cracking of the brick lining and significant loss of mortar from between the bricks has been observed in both current and previous inspections. The deteriorated condition of the brick masonry lining is probably due to the long exposure to weathering combined with hydraulic erosion from wave action and fluctuating pool levels. Although no evidence of seepage was observed during the Phase I visual inspection, the deterioration of the lining may lead to serious leakage and instability in the exterior slopes.

The continued loss of stone blocks and mortar from the 10th Street slope retaining wall could eventually cause its failure and that of the embankment. However, it was evident during the visual inspection that some repointing of the wall has been performed since its original construction.

- b. Design and Construction Data. Information is unavailable concerning the design or construction history of the embankment. It is unknown what was used for embankment materials, whether or not the embankment is zoned, has a cutoff, a grout curtain, or an impervious core.
- c. Operation Records. The City of Wilmington maintains daily records of reservoir levels and water system demand.
- d. Post Construction Changes. Remedial measures performed in 1978 for the stabilization of an interior slope failure on the Franklin Street (uphill) end of the south basin are described in Appendix G.
- e. Seismic Stability. The dam is located within Seismic Risk Zone 1 of the Seismic Zone Map of Contiguous States. A dam located in Seismic Zone 1 is generally considered to be safe under any expected earthquake loading if it is safe under static loading conditions.

SECTION 7

ASSESSMENT, RECOMMENDATIONS, AND PROPOSED REMEDIAL MEASURES

7.1 Dam Assessment

- a. Safety. The visual observations and review of available information indicated that the Cool Spring Reservoir Dam is in fair condition.

The occurrence of an interior slope failure following full drawdown of the south basin as described in Section 1.2.g indicates that the structural stability of the embankment slopes is questionable. In addition, the continued deterioration of the brick lining is reducing its effectiveness as an impervious barrier which could lead to leakage and instability conditions in the exterior slopes.

The drain system is capable of discharging about 70 percent of the PMP without overtopping the earth embankment. Additional reduction of overtopping potential is realized from the water system demand imposed upon the reservoir and the presence of City personnel on-site 24 hours a day. Therefore, the drain system is classified as adequate.

- b. Adequacy of Information. The available information provided by the City of Wilmington, along with visual observations made during the inspection, are considered to be adequate for a Phase I investigation.
- c. Urgency. The further investigations and recommended remedial measures should be implemented in the near future.
- d. Necessity for Further Investigations. Further investigations are necessary for this site. Although there is presently no evidence that the exterior slopes of the reservoir are unstable, the loss of integrity of the brick lining could lead to serious leakage and instability problems in the exterior slopes. Therefore, a study should be initiated to evaluate the effectiveness of the brick lining as an impervious barrier.

7.2 Recommendations, Remedial Measures

a. Facilities.

1. Piezometers should be installed to determine the phreatic surface within the embankment.
2. A subsurface investigation should be performed during the piezometer installations to determine the composition and properties of the embankment and foundation materials. Soils test and stability analyses should be performed to assess existing conditions.
3. The stone masonry retaining wall supporting the 10th street slope should be repointed and the missing stone blocks replaced to maintain the wall's structural integrity. According to the Owner's representative, this work is presently under way.

b. Operation and Maintenance Procedures

1. Future reservoir drawdowns should be performed at a slow rate to allow safe dissipation of possible excess pore pressures within the embankment. Procedures should be established for reading water levels in the piezometers at regular intervals during drawdown to insure a safe balance between the reservoir pool and the phreatic surface within the embankment.
2. The period of time that the basins remain empty during cleaning operations should be minimized. This procedure will reduce the possibility of excess pore pressure development within the Franklin Street slopes which are exposed to the regional ground-water table.
3. Since the normal operating pool level fluctuates to within 1.5 feet of the dam crest, the Owner should develop and implement procedures for frequent or continuous measurements of reservoir stage during periods of heavy rainfall. As an alternative, the Owner could install an audible high stage warning device to alert operating personnel of extreme high reservoir elevations.

APPENDIX

A

**Check List Engineering Data
Design, Construction, Operation
Phase I**

CHECK LIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

NAME OF DAM Cool Springs Reservoir Dam
ID # DE 00014

ITEM

AS-BUILT DRAWINGS

REMARKS

Two drawings available showing reservoir plan.
One partial plan and section drawing of south basin.

Sheet 1 of 4

REGIONAL VICINITY MAP
Refer to Appendix E, Plate 1.

CONSTRUCTION HISTORY
Refer to Appendix E.

TYPICAL SECTIONS OF DAM
Refer to Appendix E.

OUTLETS - PLAIN
DETAILS }
CONSTRAINTS }
DISCHARGE RATINGS None Available

RAINFALL/RESERVOIR RECORDS Daily reservoir levels maintained by the City of Wilmington.

ITEM	REMARKS
DESIGN REPORTS	Not available
GEOLOGY REPORTS	Not available
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM STABILITY SEEPAGE STUDIES	No data available
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY } FIELD }	Not available.
POST-CONSTRUCTION SURVEYS OF DAM	Partial survey of south basin performed in March 1978.
BORROW SOURCES	Unknown.

Sheet 3 of 4

ITEM	REMARKS
MONITORING SYSTEMS	Staff recorder situated on center dike for measuring reservoir levels.
MODIFICATIONS	Repairs to south basin performed in 1978
HIGH POOL RECORDS	According to the city's representative the high pool was at Elev. 146.0 MSL.
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	Four engineering studies performed by O'Brien & Gere Engineers, Inc. between May 1977 and August 1978.
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	An interior slope failure occurred in the uphill end of the south basin in February 1978. See Appendix G.
MAINTENANCE OPERATION RECORDS	Daily water system demand and pool levels are available and the City maintains personnel on-site 24 hours a day. The south basin has been drawn down for cleaning as described in Section 1.2.g.

Sheet 4 of 4

ITEM	REMARKS
SPILLWAY PLANS	
SECTIONS	N/A
DETAILS	
OPERATING EQUIPMENT PLANS & DETAILS	Schematic of piping and valves for control of intake and discharge at Cool Spring Reservoir.
MISCELLANEOUS	

APPENDIX

B

Check List

Visual Inspection

Phase I

**CHECK LIST
VISUAL INSPECTION
PHASE I**

Sheet 1 of 4

Name Dam Cool Spring Reservoir Dam County New Castle State Delaware National ID # DE 00014
Type of Dam Earth Hazard Category High
Date(s) Inspection May 24, 1979 Weather Overcast w/rain Temperature 70°

Pool Elevation at Time of Inspection 145.0 M.S.L.
(as read from a stage recorder at 10 a.m. on 5/24/79) Tailwater at Time of Inspection - M.S.L.

Inspection Personnel:

<u>Mr. Lee H. DeHeer</u>	<u>Mr. Leonard R. Beck</u>	<u>Mr. David B. Campbell</u>
Mr. Steve H. Snider		

Mr. Steve H. Snider _____ Recorder

Remarks:

Accompanied by Mr. John Hanley of the City of Wilmington, Water Department.

EMBANKMENT

Sheet 2 of 4

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
-----------------------	--------------	----------------------------

SURFACE CRACKS

None noted

UNUSUAL MOVEMENT OR
CRACKING AT OR BEYOND
THE TOE

None noted

None

SLOUGHING OR EROSION OF
EMBANKMENT AND ABUTMENT
SLOPES

None noted

None

VERTICAL AND HORIZONTAL
ALIGNMENT OF THE CREST

No misalignments noted

None

RIPRAP FAILURES

The brick masonry is cracked and samples of cement mortar are soft. The shotcrete placed over the brick is cracked and spalled in some locations.

Repair to the lining as necessary to provide an impervious blanket.

EMBANKMENT

Sheet 3 of 4

REMARKS OR RECOMMENDATIONS

VISUAL EXAMINATION OF

OBSERVATIONS

JUNCTION OF EMBANKMENT
AND ABUTMENT, SPILLWAY
AND DAM

N/A

None

ANY NOTICEABLE SEEPAGE

None noted

None

STAFF GAGE AND RECORDER

Staff gage in serviceable condition

None

DRAINS

Basin drains are submerged.

None

OUTLET WORKS

<u>VISUAL EXAMINATION OF</u>	<u>OBSERVATIONS</u>	<u>REMARKS OR RECOMMENDATIONS</u>
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	N/A	None
INTAKE STRUCTURE	Gatehouse for intake and outlet control is newly rebuilt and in good condition.	None
OUTLET STRUCTURE	N/A	None
OUTLET CHANNEL	N/A	None
EMERGENCY GATE	N/A	None

APPENDIX

C

Hydrologic & Hydraulic Data

TABLE OF CONTENTS - APPENDIX C

PMP DATA	SHEET 1
COOL SPRING RESEVOIR STAGE-STORAGE	SHEET 2
RESERVOIR DRAIN HYDRAULICS	SHEET 3
DRAWDOWN CALCULATIONS	SHEET 4



O'BRIEN & GERE

SUBJECT

COY SPRING RES. DAM INSP. PHILA. C.O.E. 1/4 SHS 5/1/79

SHEET

BY

DATE

JOB NO.

HYDROLOGY CALCULATIONS

DRAINAGE AREA - Reservoir is isolated from surface run-off.

RESERVOIR AREA \approx 7 acres

6-hour, 10 sq. mile PMP = 26.5 inches
Zone 6

The drainage area is considered equal to the reservoir area.

Since the surface area is less than 10 sq. miles, no reduction reflecting basin size is included. However, a reduction of 20% is included to account for imperfect fit of basin and storm isohyets.

\therefore 6-hour PMP = 21.2 inches

48-hour PMP = $1.27(21.2)$ = 26.9 inches

Since no inflow or outflow is considered, the 6-hour PMP is applied to the reservoir. The rainfall distribution is such that most of the precipitation occurs within the first six hours and would most severely tax the drawdown capability of the drain system.

ECT	SHEET	BY	DATE	JOB NO.
26	SPRING RES. DAM INSP. PHILA. C.O.E.	2/4	SHS	5/1/79

The south basin storage capacity at 8 ft. is 21.9 A-F.

The average discharge through the 12" drain pipe is assumed to be about 5.5 cfs. Since no information is available concerning the location, length and elevation of the outlet of the 12" pipe; an orifice equation will be used to calculate drawdown time.

$$\text{Orifice Eqn. } Q = CA \sqrt{2gH}$$

Assume 12" pipes discharge into sewers at atmospheric pressure.

$$\text{Let: } Q = Q_{\text{avg.}} = 5.5 \text{ cfs}$$

$$A = \pi d^2/4 = \pi/4 = 0.785 \text{ ft}^2$$

$$H = H_{\text{avg.}} = 4 \text{ ft.}$$

$$C = Q / A \sqrt{2gH}$$

$$= 5.5 / 0.785 [2(32.2)4]^{0.5}$$

$$C = 0.44$$

\hookrightarrow conservatively low orifice coefficient which results when all of the other values in the equation are given.

SHEET	BY	DATE	JOB NO.
20' SPRING RES. DAM INSP. PHILA. C.O.E.	3/4 SHS	5/1/79	

TIME OF DRAWDOWN - NORMAL OPERATING POOL

H (ft.)	$Q = 0.44A(2gH)^{1/2}$ (cfs)	$Q_{avg.}$ (cfs)	V (AF)	T (hrs.)
16	11.1			
14	10.4	10.8	6.6	7.4
12	9.6	10.0	6.4	7.6
10	8.8	9.2	6.2	8.2
8	7.8	8.3	6.0	8.8
0	0	5.5	21.9	48.0

$$\Sigma T = 80 \text{ hrs.}$$

Therefore, if both 12" drain pipes were opened the reservoir could be emptied in about 3.5 days. Note that this calculation excludes dry discharges into the water system which could significantly reduce the drawdown time.



OBRIEN & GERE

SUBJECT

COOL SPRING RES. DAM INSP. PHILA. C.O.E.

SHEET

BY

SHS

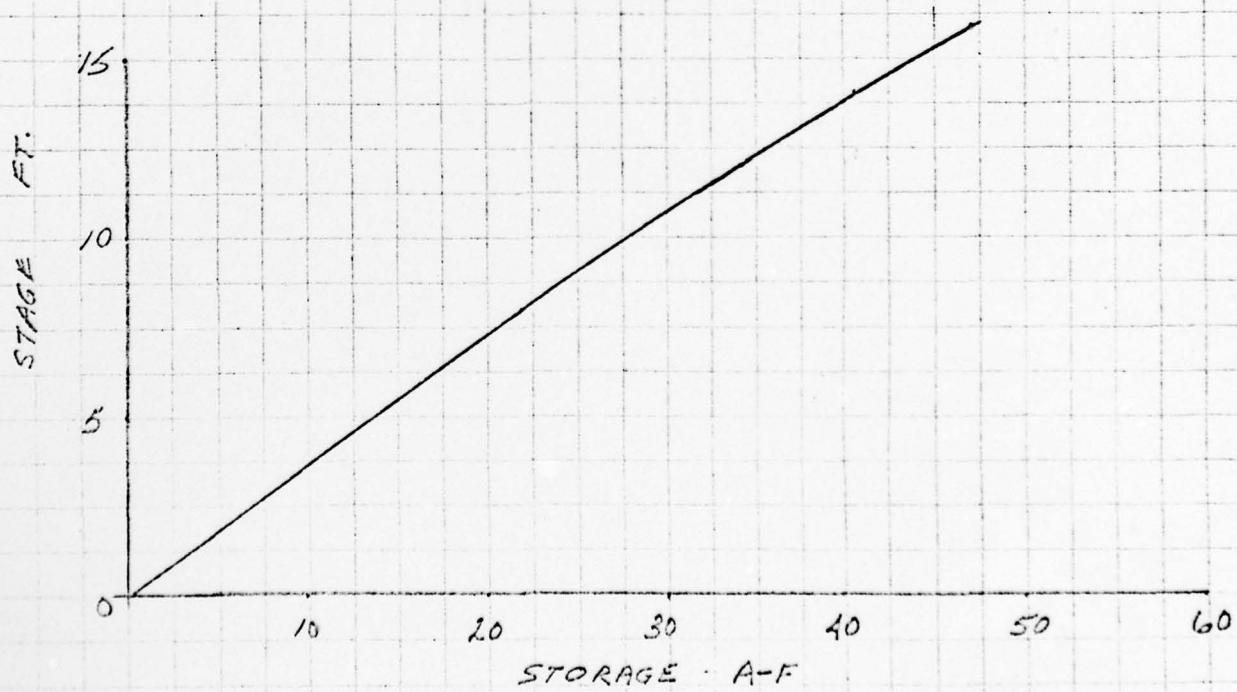
DATE

5/1/79

JOB NO

DRAWDOWN CALCULATIONS

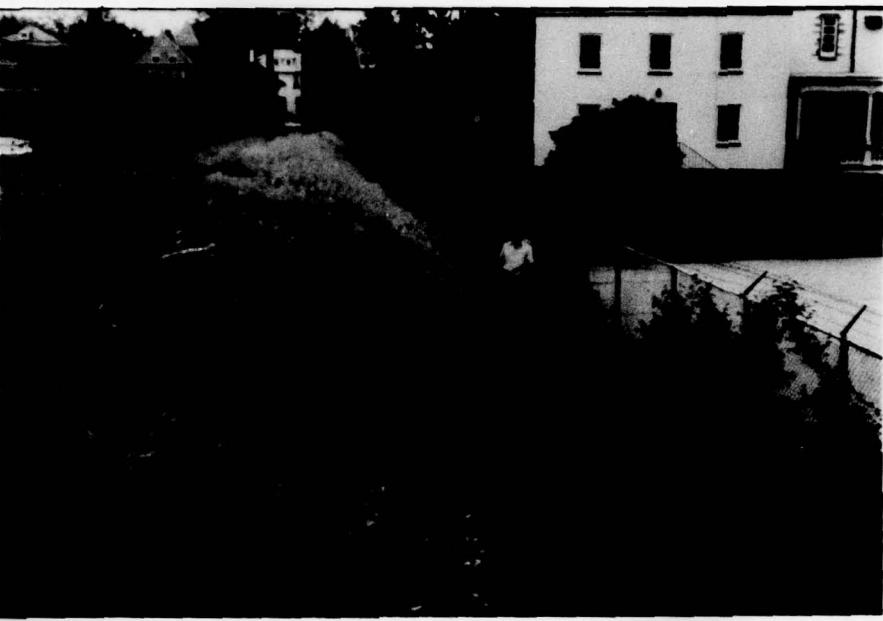
Each of the two basins in the reservoir can be drained through a 12" pipe discharging into the City sewer system. According to the owner's representative, the lower 8ft. of the south basin was drained through the 12" pipe in about 48 hrs.



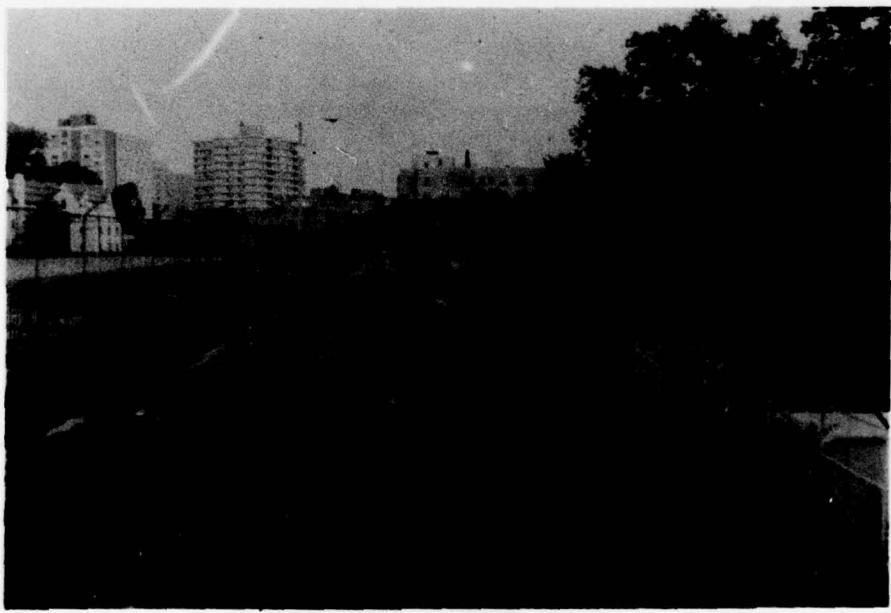
APPENDIX

D

Photographs

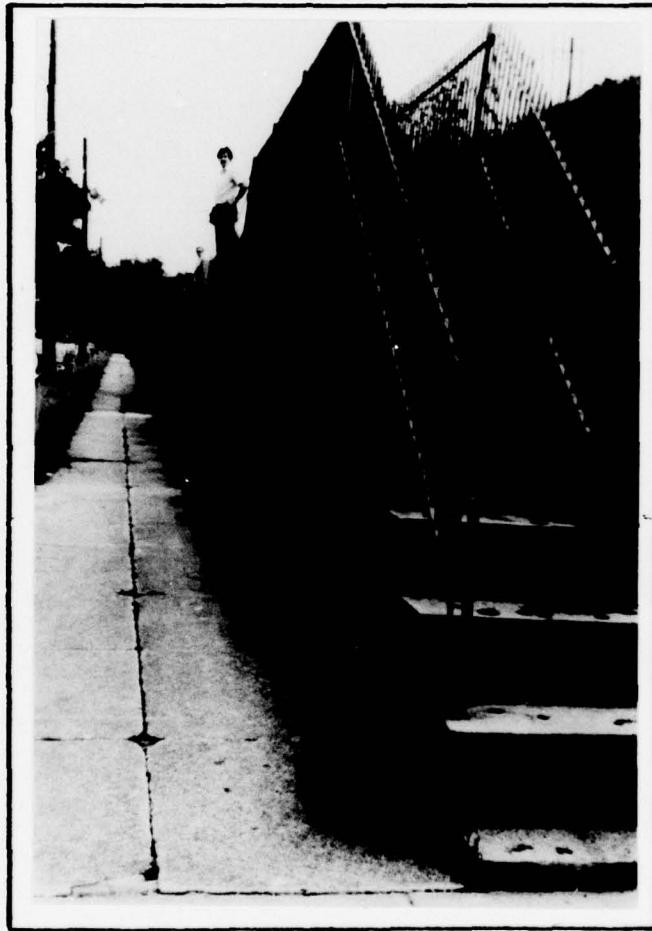


NORTH SIDE OF THE RESERVOIR SHOWING
EXCELLENT VEGETATIVE COVER 5/24/79



VAN BUREN STREET (EAST SIDE)
SIDE OF THE RESERVOIR 5/24/79

D-1



TENTH STREET (SOUTH) SIDE 5/24/79
OF THE RESERVOIR SHOWING
THE STONE MASONRY RETAINING WALL

D-2



FRANKLIN STREET (WEST) SIDE OF THE SOUTH BASIN SHOWING
THE SLOPE FAILURE IN THE SOUTH BASIN
FEB. 1978

D-3

APPENDIX

E

Drawings

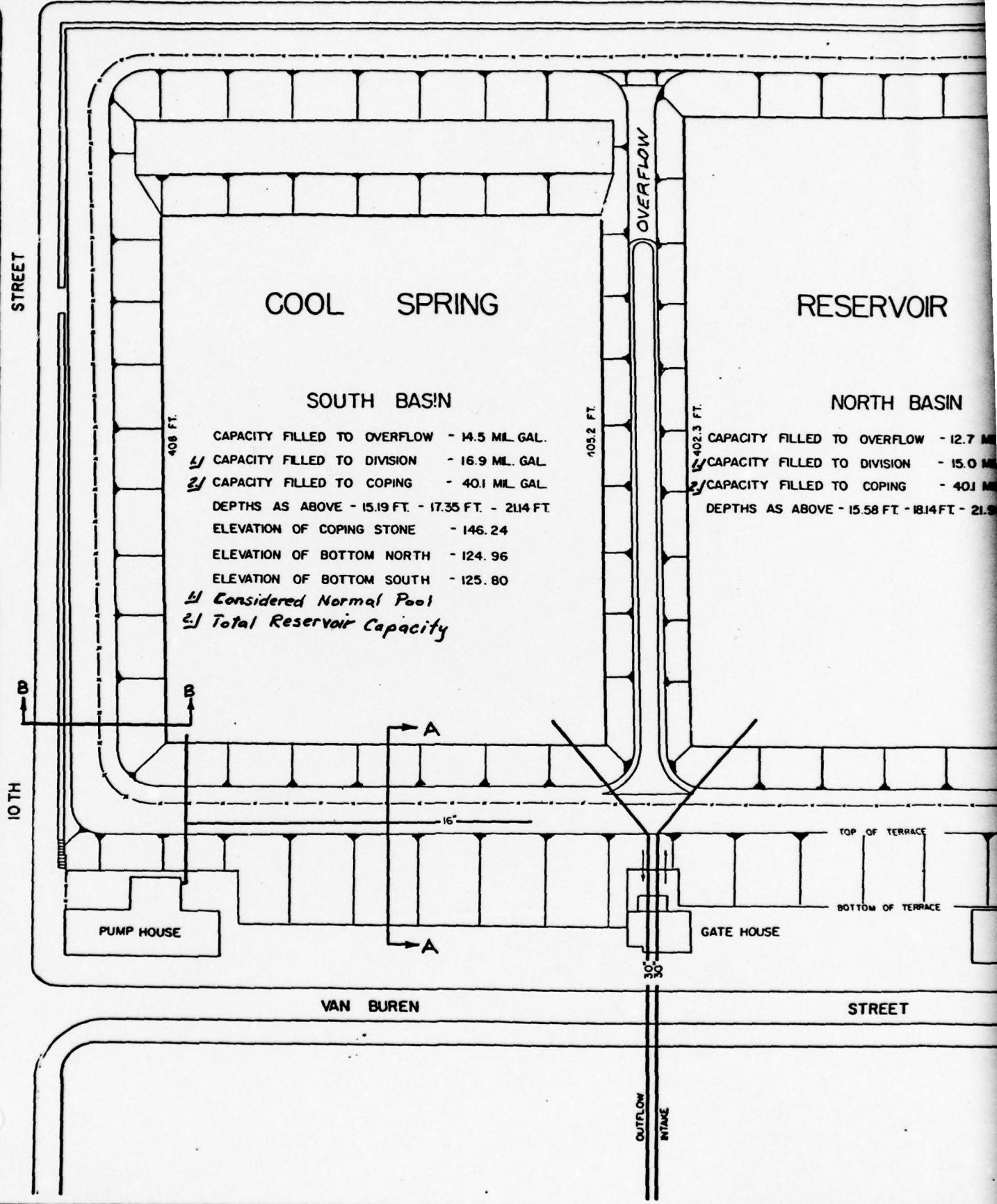
TABLE OF CONTENTS - APPENDIX E

REGIONAL VICINITY MAP	PLATE 1
COOL SPRING RESERVOIR - PLAN	PLATE 2
EMBANKMENT CROSS SECTIONS	PLATE 3



PLATE 1
REGIONAL
VICINITY MAP
SCALE 1:24000

FRANKLIN



STREET

N
12.7 MIL. GAL.
15.0 MIL. GAL.
40.1 MIL. GAL.
[- 21.98 FT.

TOP OF TERRACE
BOTTOM OF TERRACE

GARAGE

PENNSYLVANIA

AVENUE

PLATE 2

FIGURE

COOL SPRING RESERVOIR PLAN

G JUSTIN & COURTNEY
DIVISION OF O'BRIEN & GERE ENGINEERS

DATE:
DEC.
1977

ELEV.-MSL

150 -

145 -

140 -

135 -

130 -

125 -

120 -

SOUTH
BASIN

1.5

EL. 146.5

16"φ C.I. Pipe

1

2

SECTION A-A

VAN BUREN ST. (East) SLOPE

150 -

145 -

140 -

135 -

130 -

125 -

10TH STREET

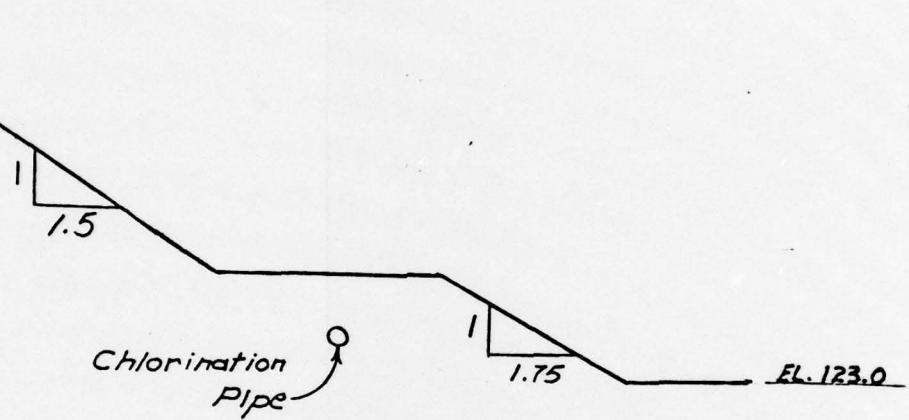
EL. 146.5
1.5
Stone
Masonry
Wall

1.5

120 -

SECTION B-B

10TH ST. (South) SLOPE



SOUTH
BASIN

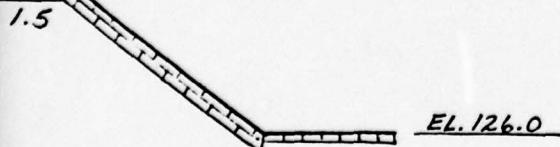


PLATE 3
COOL SPRING RESERVOIR
EMBANKMENT SECTIONS
WILMINGTON, DE
Scale: 1" = 10' May 1979

 O'BRIEN & GERE

2

APPENDIX

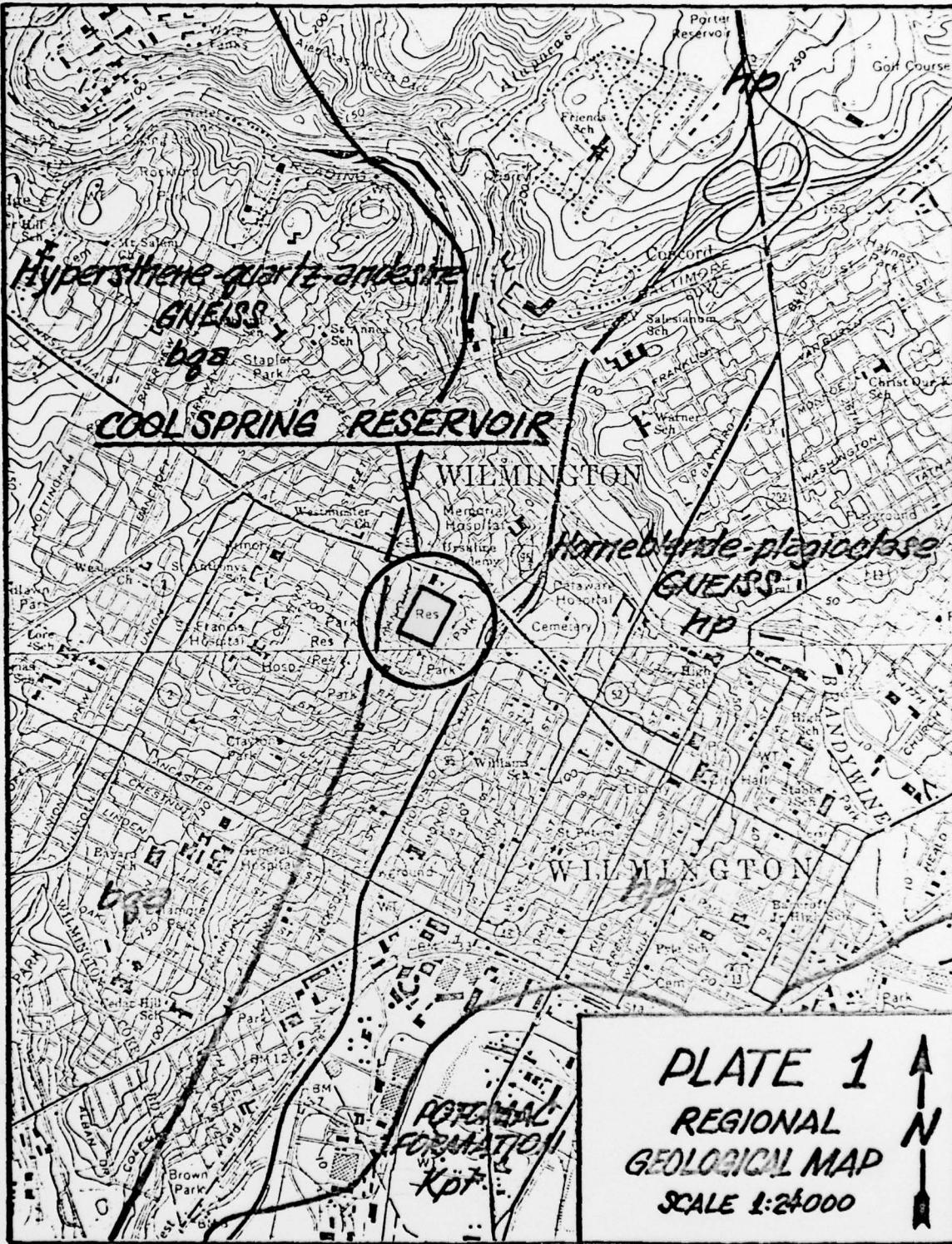
F

Site Geology

SITE GEOLOGY

COOL SPRING RESERVOIR

Cool Spring Reservoir is located in the Lowlands Section of the Piedmont physiographic province. Bedrock at the site is the Paleozoic Wilmington Complex which is composed of banded gneiss with prominent amounts of gabbro, amphibolite and granite. These metamorphic and igneous rocks have differentially weathered *in situ* such that their character varies from a hard rock mass to a soil like material exhibiting cohesion and/or granulation.



APPENDIX

G

Structural Stability Data

APPENDIX G

PREVIOUS INVESTIGATIONS AND REPORTS

Repairs to

COOL SPRING RESERVOIR

**CITY OF WILMINGTON
DEPARTMENT OF PUBLIC WORKS**

August 1978

**O'BRIEN & GERE
Justin & Courtney Division**

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	<u>SECTION</u>
I PROJECT DESCRIPTION	1 - 2
II CONSTRUCTION	3 - 5
III CONCLUSIONS AND RECOMMENDATIONS	6 - 7

I. PROJECT DESCRIPTION

Cool Spring Reservoir is an uncovered, brick lined treated water reservoir with a capacity of 40 million gallons, constructed in Wilmington, Delaware between 1873 and 1877. The reservoir, divided by a 16.5 foot high dike into two basins, has a maximum depth of 22 feet and covers an area of about 7 acres.

Justin & Courtney, Inc. was retained in December of 1976 to investigate the feasibility of covering the reservoir. Late in August of 1977, while the south basin was drained for cleaning, bulging of the toe at the west end of the center dike, cracking of the brick lining, leakage of water through the dike and a large sand boil on the floor of the basin were observed. A detailed inspection revealed similar conditions at other locations within the south basin. It was concluded that the clay and brick lining of the center dike had lost its effectiveness in sealing the reservoir, which resulted in saturation of the embankment. A rapid solution to the problem was necessary since the potential existed for further failure of the slopes. The recommended permanent solution was to re-line the basin and install an embankment drainage system along the Franklin Street end of the basin. However, the large capital expenditure required for this work and the need to have the basin in service as soon as possible necessitated the development of temporary measures. These measures included:

1. Covering the failure area with filter cloth and a 2 foot high toe berm constructed of sand and gravel.
2. Installation of perforated pipe in the toe berm to drain the embankment during future drawdowns.
3. Guniting over the toe drain and cracked brick lining to protect the embankment from further saturation from the reservoir.

Details of this work are shown on Drawings 1 and 2, entitled "Cool Spring Reservoir Repairs," City of Wilmington Contract No. 78017. A contract for this work was awarded to Marcozzi Enterprises, Inc. on December 15, 1977.

II. CONSTRUCTION

The contractor started work on January 16, 1978 and began experiencing difficulty moving equipment across the south basin floor due to the saturated condition of the clay underlying the brick floor. The areas damaged by the movement of construction equipment over the basin floor were covered with filter fabric and Delaware-type 106 stone. Severe weather conditions caused frequent work suspensions which delayed progress of the work during this time. By January 20, a one foot deep trench about 50 feet long, which was to be filled with filter sand, had been excavated along the toe of the Franklin Street slope.

Between January 25 and January 27, a slope failure occurred on the Franklin Street slope of the south basin. The initial inspection of the site on January 28 revealed a slide about 180 feet long, with a vertical displacement of about 2 feet, and extending about 25 feet into the basin. A groundwater reading in an adjacent piezometer indicated a 2 foot rise in the water table since the last measurement was taken in October, 1977. The unbalanced hydrostatic forces developed within the embankment during the time that the basin was empty was believed to be the main contributing factor to the slope failure.

Wooden stakes were placed along the top of the embankment to measure the vertical displacement of the slide. Detailed information concerning the survey is shown on Drawing No. 5521-L, by MANN-TALLEY, INC., Engineering-Surveying, Wilmington, DE. To stabilize the slope failure, it was decided to construct a 4 foot high gravel berm at the toe of the Franklin Street slope for a distance of 100 feet southwest of the center dike and extending 25 feet into the basin. In addition, acoustic emission monitoring of the failure was undertaken to provide data on movement along the failure surface of the slope. A discussion of this technique and its application to the slope failure is included in the Appendix. Modifications were made to the existing contract for this work, but timely placement of the berm was inhibited because of poor weather.

The contractor resumed construction on February 15. By that time, the bank was subsiding at the rate of about 0.2 foot per day and had reached a maximum settlement of about 6 feet. Consideration was given to filling the reservoir to stabilize the condition and to provide time to evaluate alternate solutions to the problem. However, since the slide area had encroached on the weir portion of the center dike, it was impossible to operate the reservoir as required. It was therefore decided to immediately expand the scope of the work as follows:

1. Increase the length of the stabilizing berm to 150 feet and the height to 10 feet. (It was later decided to extend the berm the entire length of the Franklin Street end of the basin to prevent further progression of the failure along the slope.)
2. Install perforated aluminum pipe drains with flap gates at the toe of the original slope and at the toe of the berm to drain the berm during drawdown of the reservoir.
3. Line the berm with flexible lining material to prevent saturation from the reservoir and contamination of the water in the basin from external sources.

Operations resumed with the stone fill being placed in the berm at a rate of about 600 tons per day. By February 27 the failure had stabilized after a total vertical displacement of about 8 feet. The average height of the berm by that date was also about 8 feet.

Two types of flexible lining material were considered; 45 mil DuPont Hypalon and 105 mil High Density Polyethelene manufactured by Schlegel Area Sealing Systems, Inc. Since Hypalon was less expensive, easier to install, and was adequate for this purpose, it was chosen for the liner. On March 9, the Hypalon material was ordered from Globe Linings, Inc. of Long Beach, CA.

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FROM COPY FURNISHED TO DDC

Placement of the stone fill progressed satisfactorily until March 13 when a void about 6 foot square and 30 cubic yards in volume was discovered in the center dike. This void had apparently developed over a long period of time and appeared to be caused by fine-grained soil from the dike piping through cracks in the brick. The collapse was triggered by the berm which was placed against the unsupported brick over the void. After the discovery of this void, the water level in the north basin was immediately lowered to Elevation 136 to reduce the hazard of failure of the center dike.

SOILTECH, a division of Raymond International, began filling the void on March 17 with an air-entrained, 2 : 1 sand-cement grout. A plasticizer was added to insure complete filling of the void, since the condition of the brick prevented the use of pressure. The locations of other voids within the weir portion of the center dike were determined by taking measurements in 20 holes bored in the concrete cap. Additional grouting was done through these holes (see Figure 2), but was terminated when grout was observed flowing into the north basin through the lining at the base of the dike. Grouting along the north basin side was not completed because of the difficulties involved in sealing the slope on the north basin side, which would have necessitated the use of a diver or draining of the north basin. The total grout placed in the center dike was 36 cubic yards.

By March 27, the contractor had completed the berm and was preparing the site for installation of the Hypalon. Globe Linings, Inc. began placement of the liner on March 29 and completed the installation on April 5, 1978, less than one month after the lining material was ordered.

Filling of the south basin began on April 11 and two days later the water level had reached a depth of 9 feet. This level was maintained until mid-April when water was allowed to spill over the weir into the south basin from the north basin. Full operation of the south basin resumed in the latter part of April, 1978.

III. CONCLUSIONS AND RECOMMENDATIONS

The slope failure and the appearance of bulges in the slopes at other locations in the south basin leads to the conclusion that the stability of the slopes is questionable, especially during periods of reservoir drawdown. Additional failures of the internal slopes are likely to occur when the basins are drawn down again. To minimize the probability of additional failures, future drawdowns should be made at a slow rate to allow the pore water pressures in the saturated portions of the embankments to dissipate and the period of time the basins remain empty should be kept to a minimum. There is presently no evidence that the exterior slopes of the reservoir are unstable, but the loss of integrity of the brick lining could lead to serious leakage and instability problems in the exterior slopes. Failure of the exterior slopes, of course, would have much more serious consequences than failure of the interior slopes and would be a serious threat to public safety.

The large void discovered in the center dike appears to be the result of internal erosion of the embankment, which has been occurring for a long period of time. Only partial filling of these voids was accomplished during the remedial repairs. Other voids may exist within the embankments, since a complete investigation of the embankments was not performed.

These conditions emphasize the need for further investigations, which should include the following work:

1. Drilling additional bore holes in the embankments around the reservoir and in the center dike. The soil samples obtained from these borings should be subjected to laboratory analysis to determine the grain size, plasticity, permeability and strength characteristics of the embankment and foundation materials.

2. Installation of wellpoint piezometers in selected bore holes to monitor groundwater levels in the embankments. These piezometers should be monitored on a regular basis.
3. Analysis of the data obtained from the borings and piezometer measurements to determine whether dangerous conditions exist in the embankments.